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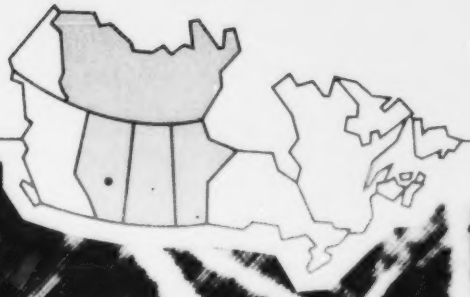
Daedalus line scanner trials in Alberta, 1985 and 1986

C.J. Ogilvie and R.W. Young



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DAEDALUS LINE SCANNER TRIALS IN ALBERTA, 1985 AND 1986

C.J. Ogilvie[1] *and R.W. Young*[2]

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NORTHERN FORESTRY CENTRE
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ABSTRACT

Methods used to test the small-fire detection capabilities of a Daedalus 1260 and 1268 infrared scanner mounted in a King Air 200 aircraft are described. The targets used for the trials were pans containing from 1 to 125 charcoal briquettes. The targets were replicated 10 times and were positioned under various forest canopies. The scanner was flown at several altitudes and offsets over each target array, and the number of targets detected was recorded. The best results were obtained when the targets were placed in pine stands; any significant amount of spruce in a stand severely hampered detection. It was concluded that the equipment would be effective if there was a reliable lightning fire prediction process to reduce the number of search areas or if the scanner was used on relatively small areas of high priority.

RESUME

Ce document décrit les méthodes employées pour déterminer l'efficacité d'un scanner infrarouge Daedalus 1260 et 1268 monté dans un avion King Air 200 pour la détection de petits incendies. Les cibles utilisées pendant les essais étaient des bacs contenant de 1 à 125 briquettes de charbon de bois. Ces bacs ont été disposés en 10 groupes sous différents couverts forestiers. Des vols ont eu lieu à des altitudes et à des angles différents et le nombre de cibles détectées a été noté. Les auteurs ont obtenu les meilleurs résultats quand les cibles se trouvaient dans des pinèdes—le potentiel de détection était grandement réduit quand les peuplements contenaient un nombre important d'épinettes. Ils ont conclu que le matériel de télédétection serait efficace s'il existait un système fiable de prévision des incendies causés par la foudre, ce qui permettrait de réduire le nombre de zones à patrouiller, ou s'il servait au-dessus de zones relativement peu étendues, mais hautement prioritaires.

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NOTE

The exclusion of certain manufactured products does not necessarily imply disapproval nor does the mention of other products necessarily imply endorsement by Forestry Canada.

INTRODUCTION

Approximately one-half of the forest fires in the prairie provinces are started by lightning, and only 60% of these are discovered within 24 hours of origin (Kourtz 1967). The remaining 40%, which are classified as holdover fires, help to complicate forest fire control. Due to fuel conditions that temporarily will not support rapid combustion, not enough smoke is emitted to allow these fires to be detected visually. When the fuel dries enough to support rapid combustion, however, the fires become active and "take off." This often results in fires that are difficult to control.

Infrared (IR) line scanners have been developed that have the potential to locate some of these fires by detecting heat emission before the critical stage is reached. One IR line scanner being used for fire control work is commercially manufactured by Daedalus Inc., of Ann Arbor, Michigan. A Daedalus scanner and its support systems operated by the National Safety Council of Australia was leased by the British Columbia Ministry of Forests and Lands, the Alberta Forest Service (AFS), and Conair Aviation Ltd., for 45 days during July and August of 1985. It was rented in 1986 for 62 days by Alberta, British Columbia, the Saskatchewan Department of Parks, Recreation and Culture, Northwest Territories Department of Renewable Resources, and Yukon Forest Service. The purpose of leasing the system was to acquire and then evaluate data for holdover fire detection, fire mapping, fire behavior studies, and forest resource surveys.

This report describes test results from the IR line scanner trial conducted jointly by the AFS and Forestry Canada for holdover fire detection, which determined the sizes of heat sources detectable in open areas and the effects of various stand densities and composition on detectability.

METHODS

The methods used in this evaluation are based on work done in project Firescan of the U.S. Forest Service (Warren and Wilson 1981). Project Firescan spanned a 13-year period (1962–74) and included extensive testing for detection probability from different angles in various forest stands. Although the trials described in this report are similar to portions of the Firescan work, local conditions, different scanning equipment, and slightly different test criteria justified the Alberta trials.

System Description

The IR line scanner employed in 1985 was the Daedalus 1260 (Fig. 1), a bispectral scanner operating in the 3–5 and 8–14 micrometre (μm) bands. The bispectral feature provides a good image of objects near ambient temperature such as terrain features, which emit IR radiation primarily in the 8–14 μm band, and hotter areas such as burning forest fuels, which emit primarily in the 3–5 μm band. The system produces a continuous hard copy thermographic print of the scanned area in approximately 1 minute. In addition to the hard copy, the data is digitized and stored on computer tape for subsequent computer enhancement and analysis. The 3–5 μm detector, being the most responsive to hotter areas, is connected to a threshold-adjustable event marker that flags the imagery on the end of any scan line containing a hot spot and triggers a printer that outputs the location of the aircraft determined by the navigation system. Some of the scanner characteristics include a 2.5 milliradian instantaneous field of view at nadir and a 77°20′ total field of view. From a flying altitude of 1200 m, this translates to a 1900 m swath with 3-m pixels at nadir.

The 1986 Trials

Additional testing was done in 1986 due to a change in the scanner specifications. The 1260 scanner optics were changed to 1268 specifications, which allow twice the sensitivity at any given altitude but only one-half of the field of view. The methods used for testing were identical to the 1985 trial but were conducted in northwestern Alberta because of poor weather conditions in the area of the 1985 trials. Every attempt was made to select sites that were comparable to the ones used in 1985.

The aircraft employed in both years was a King Air 200 twin-engined turbo prop (Fig. 2), which has a ceiling of 9100 m, a cruising speed of 440 km/h, and a maximum range of 3000 km or 6.5 h. The navigation equipment, which is essential for night operations, was a VLF/OMEGA and an Inertial Navigation System (INS).

Data Acquisition

The scanner crew consisted of a pilot, copilot, scanner operator-electronics technician, and two IR

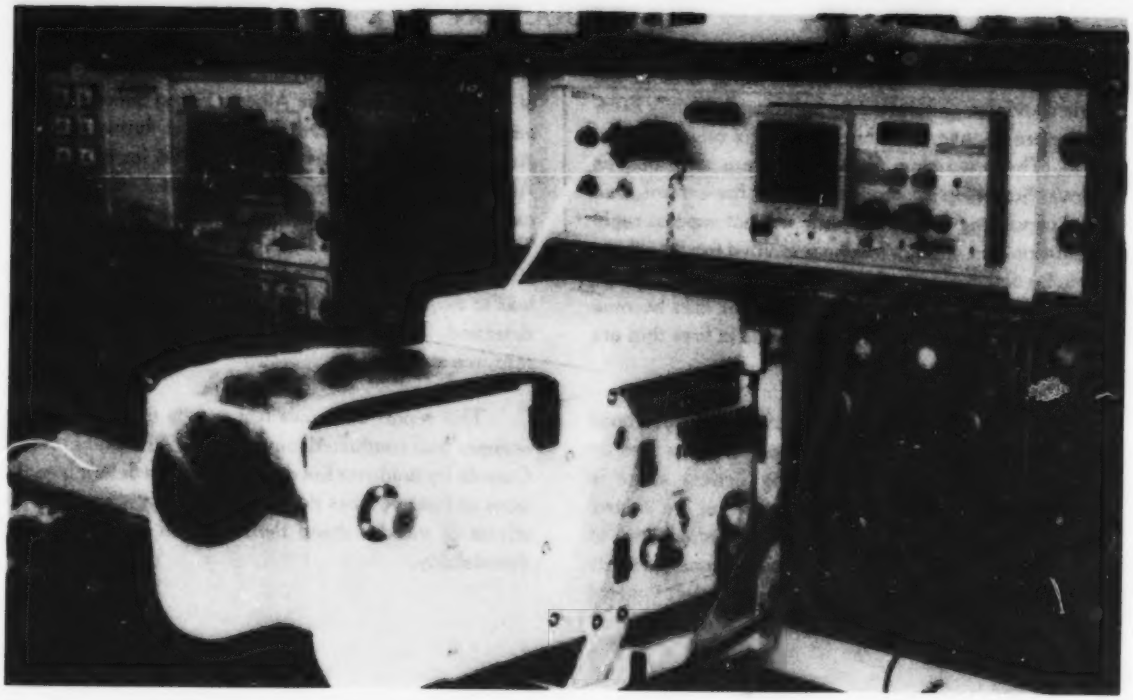

Figure 1. The Daedalus 1260 scanner.

Figure 2. The King Air 200.

interpreters, one of them an AFS employee. Two three-person ground crews established the heat sources.

The test heat sources were charcoal barbeque briquettes that burn at approximately 500°C and provide a consistent reproducible target for up to 2 h. To eliminate any reflection, the briquettes were burned in black-painted aluminum pans 25 cm in diameter.

All scanning was done at night to minimize interference from sun-heated material. The scanner platform flew for 17 h, and approximately 450 kg of charcoal were used.

In 1985 the Swan Hills area of Alberta, classified as Boreal Forest, Lower Foothills section (Rowe 1972), was chosen for the trials primarily because of the various forest cover types in proximity. In addition, there is a suitable airstrip with an AFS holding camp nearby. The 1986 trials were held near High Level, Alberta, in similar forest cover types.

The weather was clear during the trial periods in 1985 and 1986. This weather pattern resulted in warm days and cool nights with high relative humidities. Because of the high humidities, there was ground fog in some areas but not in the test stands. Daily weather statistics for July 29 to August 2, 1985, from the Swan Dive Lookout, 3 km northeast of the town of Swan Hills, and the Remote Automatic Weather Station (RAWS) W1, 24 km southeast of Swan Hills, are summarized in Table 1.

The field tests consisted of two phases: determination of heat source sizes and detection of heat sources within forest stands.

Determination of Heat Source Sizes

This first phase was designed to determine the minimum amount of heat needed to activate the 3–5 μm band event marker from various altitudes. To accomplish this, two arrays of 10 stations each were established: one on an abandoned airstrip and the other along a road running at right angles from one end of the airstrip. Each of the 10 stations had a different size of heat source, ranging from 1 briquette to 125 briquettes (Table 2). The stations were placed 60 m apart to ensure that each one would fall into a separate scan line. The aboveground levels (AGLs) chosen to provide a wide range and simultaneously reduce the number of test flights to a minimum were 1200, 2400, 4500, and 7600 m (Table 3). Four flights per AGL were made longitudinally to each array: two with the array at nadir (once each way) and two with the scanner offset to put the array near both edges of the field of view. The offset flights were made to determine how much sensitivity was lost near the edges of the total field of view.

Detection of Heat Sources within Forest Stands

The second part of the test was designed to determine what effect some typical forest stands have on heat source detectability. The Alberta Forest Service's cover type classification system was used, and the cover types selected were B2Sb, B3Pj, C3SwP, B3Sw, and C3P1 (Fig. 3). These cover types were selected with consideration to time and resource limitations and because they are typical of those where the majority of holdover fires occur. The information obtained in the first test phase was applied in this phase of the test. For example, if it was determined in the first test phase that a minimum of 15 briquettes distributed in three pans was detectable from 1200 m AGL, then the target sizes in the stands would be 15 briquettes distributed in three pans when the flying altitude was 1200 m. This procedure was repeated for the different altitudes flown.

The individual forest stand arrays consisted of 10 stations 60 m apart set out parallel to roads for easy access. Ten stations were used in an attempt to overcome the natural variability within the stands; they were established with as little bias as possible by measuring 30 m into the stand and establishing the first station, then compassing parallel to the road to establish the remaining nine. Vertical pictures were taken from each station to give an indication of the windows available to the scanner, and these are available on request.

The interference tests were started at the lowest heat source and altitude. As each step was completed, briquettes were added to the targets, and the aircraft went higher. Two stands were done simultaneously to save aircraft time. These flights were made in the same way as the control arrays, i.e., once each way at nadir and once on each side of the field of view. The pans were also arranged in the same way as the control and were not moved between successive stages of the field tests.

Table 1. Weather conditions recorded for Swan Dive Lookout and Remote Automatic Weather Station (RAWS) W1 at 0800 Mountain Daylight Time (MDT)

Date (1985)	Previous day temperature		Dry-bulb temperature (°C)	Relative humidity (%)	10-m wind (km/h)
	Maximum (°C)	Minimum (°C)			
July 29	19	11	13	70	Calm
	no data	no data	5	95	NW 2
July 30	22	9	11	79	SE 10
	22	3	3	97	Calm
July 31	22	10	12	70	SE 14
	22	6	7	98	Calm
August 1	22	12	16	69	SW 6
	23	8	7	96	Calm
August 2	27	16	16	53	NW 8
	27	10	11	95	W 3

Table 2. Size of heat sources in control arrays

Station number	Number of briquettes	Number of pans
1	1	1
2	2	1
3	4	2
4	8	2
5	15	3
6	25	5
7	50	5
8	75	5
9	100	5
10	125	5

Table 3. Flying altitudes and corresponding ground scan widths

Flying height (m AGL)	Ground scan width (m)
1 209	1 951
2 438	3 901
4 572	7 315
7 620	12 191

RESULTS AND DISCUSSION

Determination of Heat Source Sizes, 1985 Trials

The flights over the two arrays situated in the open permitted determination of the size of the minimum detectable heat source from each of the chosen altitudes. The first set of passes was made at 1200 m (Fig. 4). In one array, all stations down to and including the one that contained 15 briquettes were detected. In the other array, only the 25-briquette and larger stations were detected; this array was situated on a road that ran parallel to a slight breeze (estimated at 5 km/h) that blew only during this set of flights but could have dispersed enough heat from the 15-briquette station to make it invisible to the scanner.

The second set of flights was made at 2400 m (Fig. 5). From that altitude the 75-briquette and larger stations were visible on three out of four passes. The failure of the one pass to detect that heat level was attributed to an error in setting the threshold level in the scanner.

The third test altitude for the control plots was 4500 m. This altitude proved to be marginal even for detecting the 125-briquette heat source; only one pass in four triggered the event marker. At this time the control stage of the trials was halted because it was obvious that higher elevations would yield even poorer results, and providing a larger heat source would represent a fire that was unacceptably large.

During this stage of the trials there was no obvious difference in scanner sensitivity between nadir and the edges of the total field of view.

Detection of Heat Sources within Forest Stands, 1985 Trials

This stage of the trials was designed to determine the availability of direct line-of-sight windows to the forest floor through the various forest canopies. The most detectable combination in the two pine stands was a target size of 15 briquettes at 1200 m AGL (Table 4). Even in the best runs, however, only three or four stations out of a possible 10 were detected (Fig. 6). No stations were detected in any of the spruce types from that altitude. The poor results at this level can possibly be explained by the small target size of only five briquettes per pan (three pans). One or more pans could easily have been screened by parts of the forest canopy that would have little effect on a larger target.

The best results were obtained with 75-briquette targets and a flying height of 2400 m. The two pure pine stands provided the most consistent windows, and 10 out of 10 stations were detected in a few cases (Figs. 7, 8, Table 4). The stands containing a substantial amount of spruce effectively blocked line-of-site access to the scanner from the targets, with the best passes picking up only 5 out of 10 stations (Figs. 9–11, Table 4). The differences between the pine and spruce stands were expected and are due to the physical characteristics of the trees; the spruce crown is generally much denser than the pine.

When the arrays were more than 20° from nadir, detectability dropped substantially even in the pure pine stands (Table 4). This was due to the additional tree crowns encountered by the oblique line-of-sight.

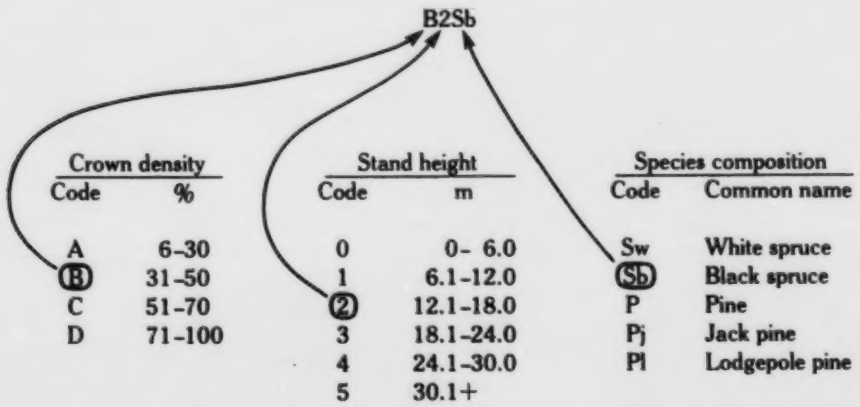

Figure 3. Alberta Forest Service cover type classification key used in the study.

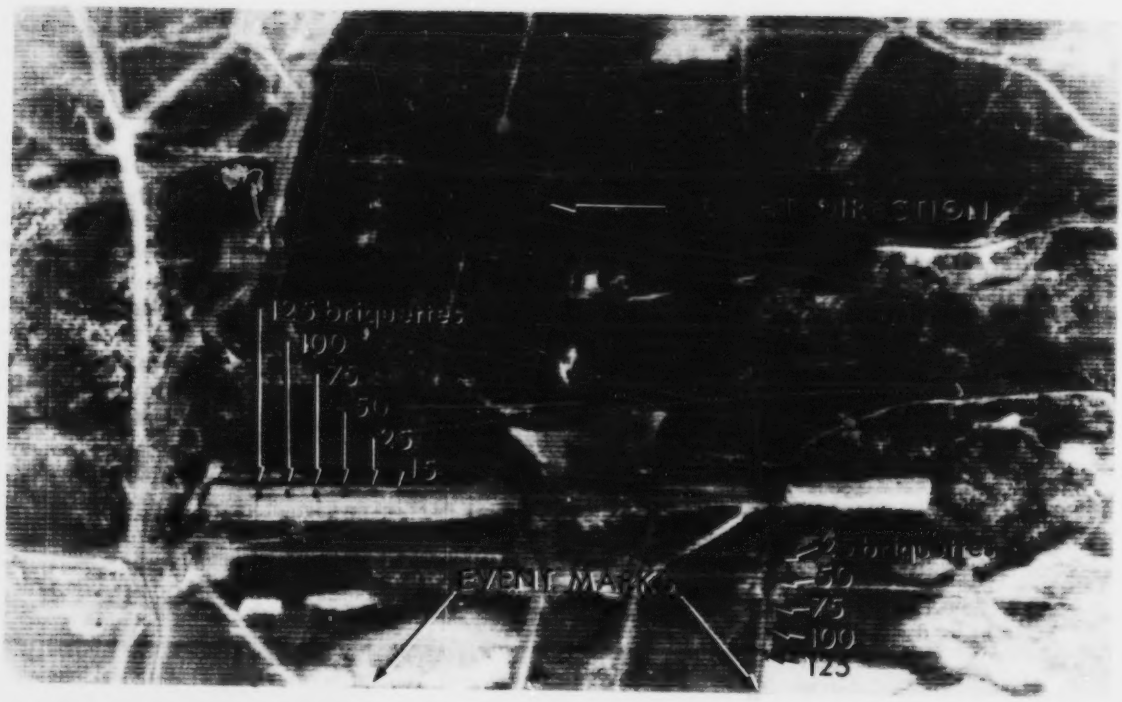

Figure 4. Control arrays from 1200 m AGL.

Figure 5. Control arrays from 2400 m AGL.

Table 4. Number of stations detected[a] (possible 10) from three altitudes

Stand[b]	15 briquettes from 1200 m		75 briquettes from 2400 m		125 briquettes from 4500 m	
	Nadir	Offset	Nadir	Offset	Nadir	Offset
B2Sb	0,0	0,0	5,5	5,0	0,0	—[c]
B3Pj	4,2	3	10,5,7,7,7	1,4	0,0,0,1,0	—
C3SwP	0,0	—	0,1	0,0,0	—	—
B3Sw	—	—	2,3	—	—	—
C3Pl	—	3,0,0	7,10,8	1,1	—	—

[a] Each number in the table represents a flight and indicates the number of stations detected on that flight.
[b] See Figure 3 for explanation of stand types.
[c] No flight made.

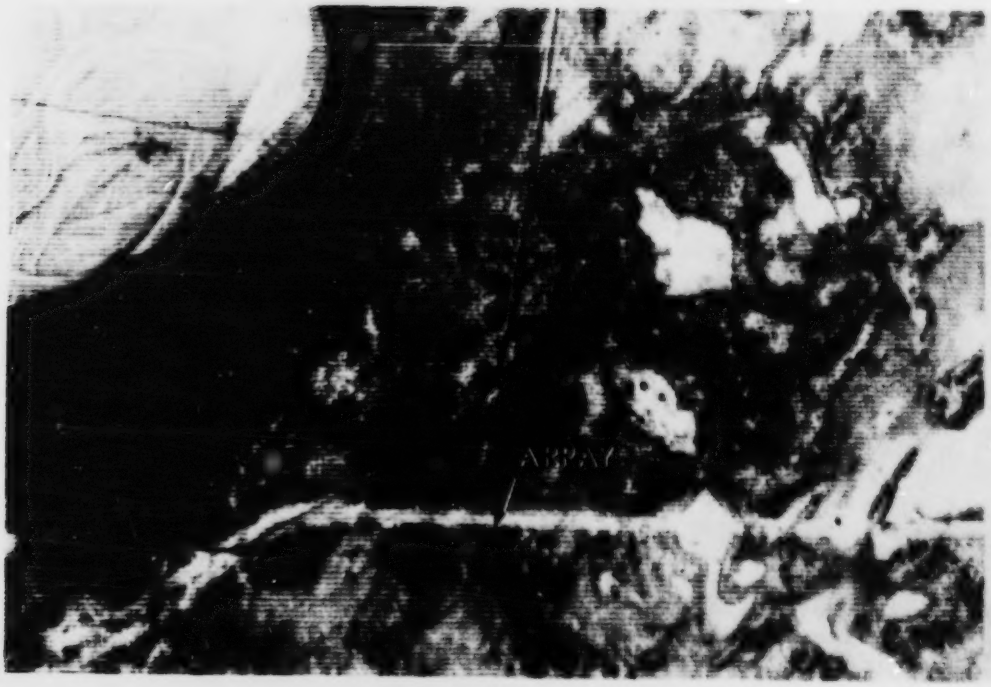

Figure 6. Jack pine, 15 briquettes at each station, 3 of 10 stations detected from 1200 m AGL.

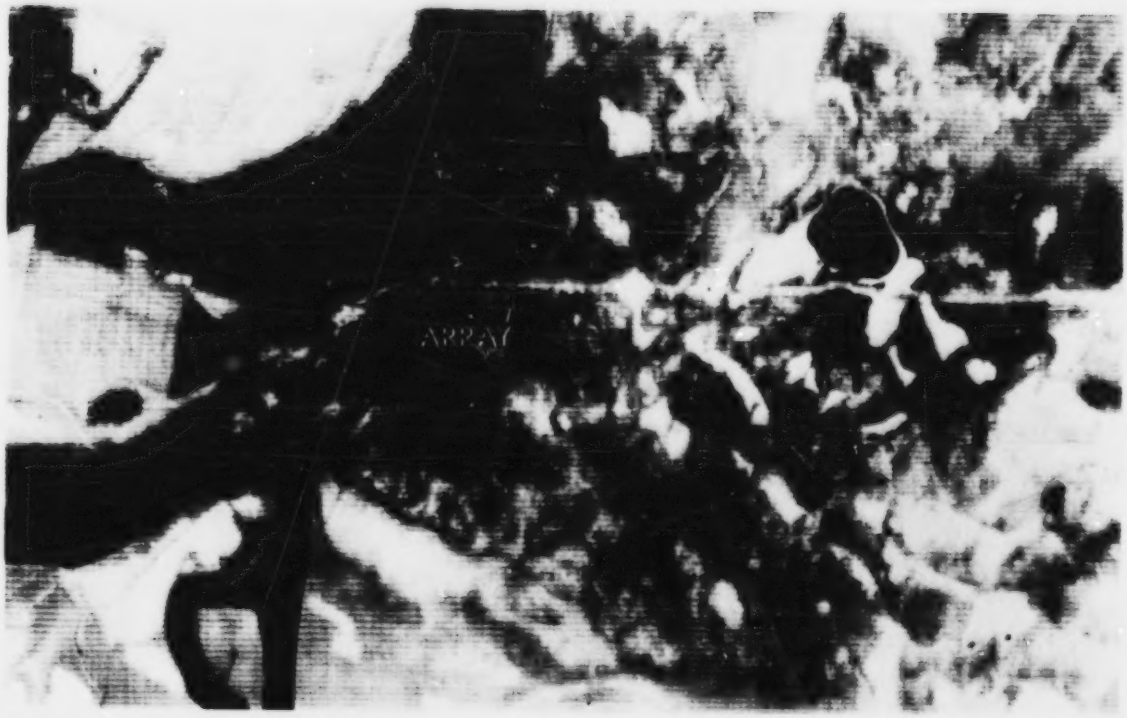

Figure 7. Jack pine, 75 briquettes at each station, 10 of 10 stations detected from 2400 m AGL.

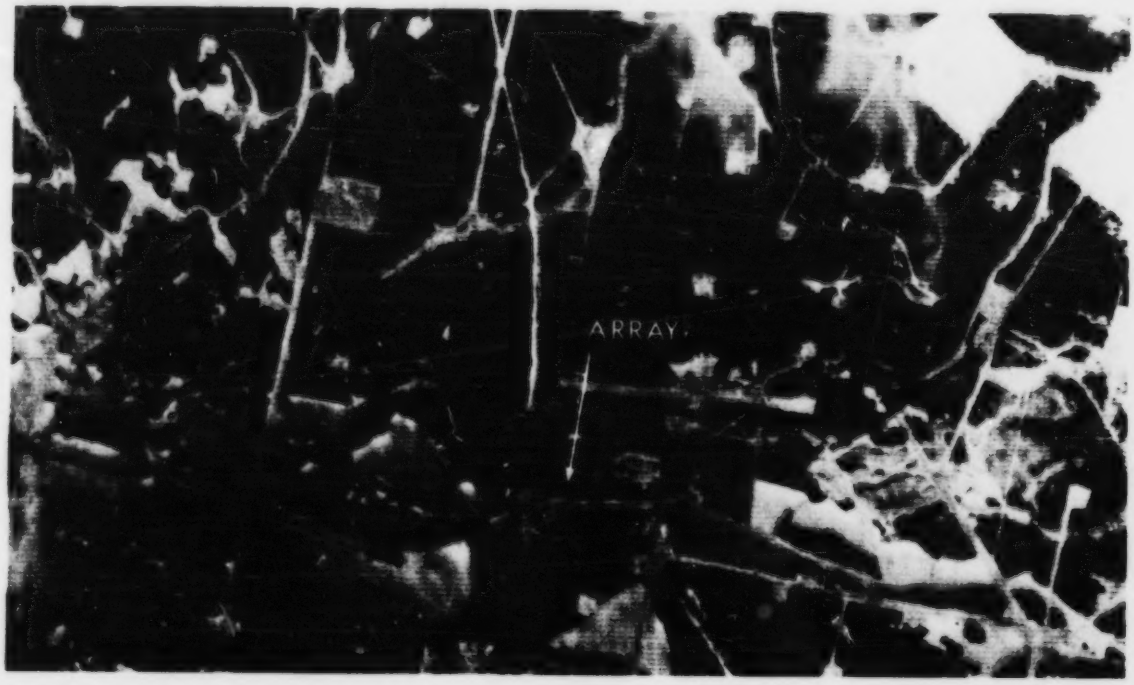

Figure 8. Lodgepole pine, 75 briquettes at each station, 8 of 10 stations detected from 2400 m AGL.

Figure 9. Black spruce, 75 briquettes at each station, 5 of 10 stations detected from 2400 m AGL.

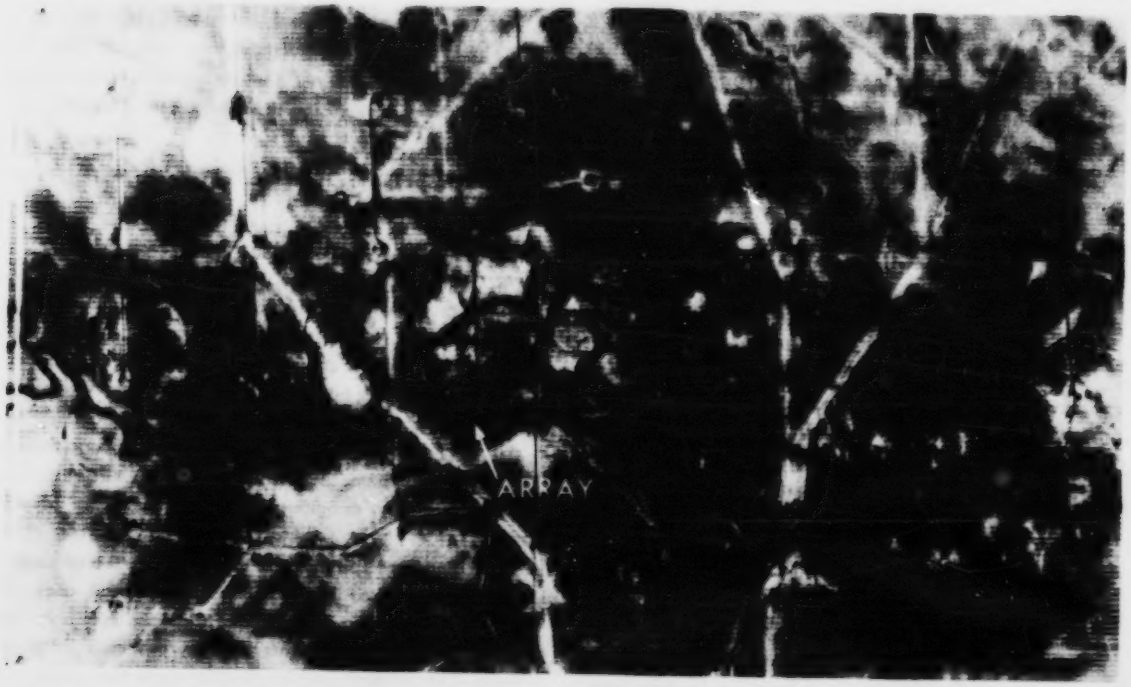

Figure 10. White spruce and pine, 75 briquettes at each station, 1 of 10 stations detected from 2400 m AGL.

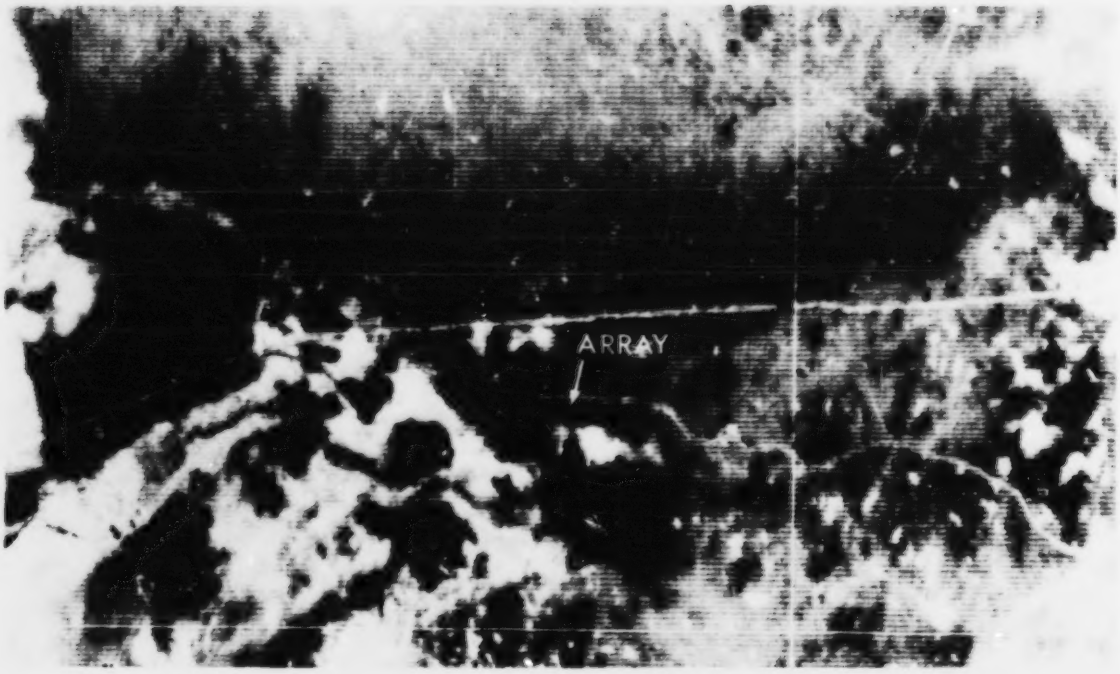

Figure 11. White spruce, 75 briquettes at each station, 3 of 10 stations detected from 2400 m AGL.

The 1986 Trials

The 1986 trials showed that the 1268 could detect the same heat sources from roughly twice the altitude as the 1260. The advantage to this is that from the higher altitude the scanner has a more vertical "look" through the forest canopy and should therefore be less affected by it. The 1986 tests were not extensive enough to prove this conclusively, but the results did indicate that high-altitude scanning will provide better detection near the edges of the field of view.

CONCLUSIONS

The Daedalus line scanner has the ability to detect low intensity heat sources in some forest stands but is severely limited in its ability to effectively scan terrain within reasonable time and cost parameters. The maximum effective altitude for the 1260 is 2400 m, which results in a scan width of 3900 m, but the lack of efficiency at the edges of the scan necessitates a 40% overlap; this reduces the scan width to approximately 2300 m. The aircraft can cruise at 440 km/h, and thus 1000 km²/h can be searched, but lightning storms can cover tens of thousands of square kilometers in an evening, making the task of covering all lightning affected areas extremely difficult and very expensive. The 1268 scanner may allow flight lines to be spaced further apart (less overlap needed), therefore reducing flying times.

If this scanner is to be used on an operational basis for detecting lightning fires, specifications for when, where, and how it should be used must be developed. There is currently no lightning fire occurrence prediction system operating in the prairie region. To decrease the size of search areas to manageable proportions, such a system would have to consider factors such as values-at-risk, fire danger conditions (Canadian Forestry Service 1984), fuel types, lightning occurrences (Krider et al. 1980), and precipitation coverage. Without a prediction system in place, the equipment could be used for searching specific high-value areas where fires are unacceptable, areas where fires have been sighted but cannot be located, and smoked-in areas that cannot be seen by conventional means.

ACKNOWLEDGMENTS

The authors would like to thank everyone involved in the trials. The work was physically demanding and required a highly cooperative attitude, which was willingly adopted by all concerned.

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